Identification of the Laminar-Turbulent Transition Process in a Plasma Plume

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Abstract

This paper illustrates the complete dynamics of the laminar-turbulent transition process in a plasma plume using a simple measurement of a stagnation-point heat flux, correlated with acoustical , optical and voltage drop fluctuations. In this manner three stages of the transition process may be identified. The first and second stages are characterised by stagnation-point heat flux increase as the mass flow rate is growing, further growth of the mass flux during the third stage results in a sharp decrease in the measured heat flux. When going from the first to the third stage, the plume flow passes through the adequate sequence of three space and time periodic flow patterns.

In the paper, the results of experimental investigation of the mechanism governing the third stage of the process are presented in detail. The correlations used were mainly these between the stagnation-point heat flux data and spectral behaviour of acoustical fluctuations. Found non-dimensional relationships between the dominant acoustical frequency (Strouhal number) and plume conditions (Reynolds number) , are nearly identical with those in air jets at ambient temperature for the "jet-column" instability and helical jet modes. Thus the rapid entrainment of the external air into the plume flow may be responsible for the sharp decrease of the stagnation point heat flux. The stagnation point heat flux reaches a minimum under the condition of the most vigorous plume oscillations; further increase in the mass flow rate causes an increase in the stagnation-point heat transfer which is governed by turbulent transport laws. This is due to the transition to small-scale turbulence in the exiting boundary layer resulting in a substantial external air entrainment decrease.

Although these results were obtained in a specific (cascaded) arc-heater design, the general transition behaviour is expected to be similar in other arc generators.